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Lead and cadmium in the liver and muscles of the mountain hare (Lepus timidus) in northern Finland[1]

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Twelve hares were shot in two areas in northern Finland (the Oulu University campus and the Värriötunturi fell area) for the analysis of lead and cadmium by direct current plasma atomic emisssion spectrometry. The concentration of lead in the liver in Oulu was around one mg per kilogramme (fresh weight), while at Värriötunturi it was only a half of that. Cadmium values in liver were highest at Värriötunturi, being about 0.4 mg/kg. The pattern of occurrence for cadmium in the muscle tissues was fairly similar to that in the liver, but at a slightly lower level on average, while the muscle values for lead showed great variation in Oulu (on average 1.2 mg/kg in 1981 and 0.3 mg/kg in 1982). The importance of the winter diet and preferred habitats of the animals (refuge theory) are discussed from the standpoint of heavy metal contamination.

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1. Introduction

Lead and cadmium content has been studied mainly in the tissues and organs of small rodents and lagomorphs in the vicinity of busy roads, smelting plants and mining sites (review in Martin & Coughtrey 1982), in addition to which Valtonen & Vikberg (1982) have found markedly high concentrations of cadmium in the liver and kidneys of the moose (*Alces alces*) throughout Finland. The present authors have studied the concentrations of lead and cadmium in the liver and muscles of the mountain hare (*Lepus timidus*) under sub-rural and wild conditions in northern Finland, with special reference to the use of direct current plasma atomic emission spectrometry (DCR-AES) in their analyses.

2. Material and methods

The mountain hares were acquired from the following places:

1. Ten hares were shot on the Oulu University campus (c. 60° N, 25° 30′E), representing a typical sub-rural area and located approx. 5 km from the city proper, in 1981 (sample I) and 1982 (sample II). Most of them had been feeding in the gardens and/or botanical garden of the university, where they had been causing a great deal of damage.

2. Two hares (sample III) were shot in the Värriötunturi fell area, eastern Finnish Forest Lapland (67° 44′N, 29° 37′E), which is in a virgin state and which is characterized by mature coniferous and mixed forests, mountain birch forests, marshes and almost treeless fell summits.

3. Three rabbits from the laboratory of the Oulu University Central Hospital were used as the comparative material (sample IV).

The animals were stored in plastic bags at −25° C. Muscle and liver samples (after removal of any remnants of lead shot) were employed for chemical analysis in the laboratory of the Department of Chemistry of the University of Oulu. The methods used were as follows.

Analytical procedures: 5–50 g was weighed out from each liver and muscle sample and digested in 30 ml of a mixture of conc. HNO_3 and H_2SO_4 (v:v = 1:1) using a Tecator Digestion System 20 equipped with an automatic temperature control (Autostep 1012 Controller). The samples were allowed to stand in the acid mixture overnight at room temperature. The next morning the temperature was first raised to 60 °C for 2 hours, and then slowly (10 °C/h) to 100°. The samples were allowed to evaporate to about 10 ml, after which 5 ml of H_2O_2 was added carefully. This addition was repeated until the black colour of the solution had changed to pale yellow. The samples were then diluted

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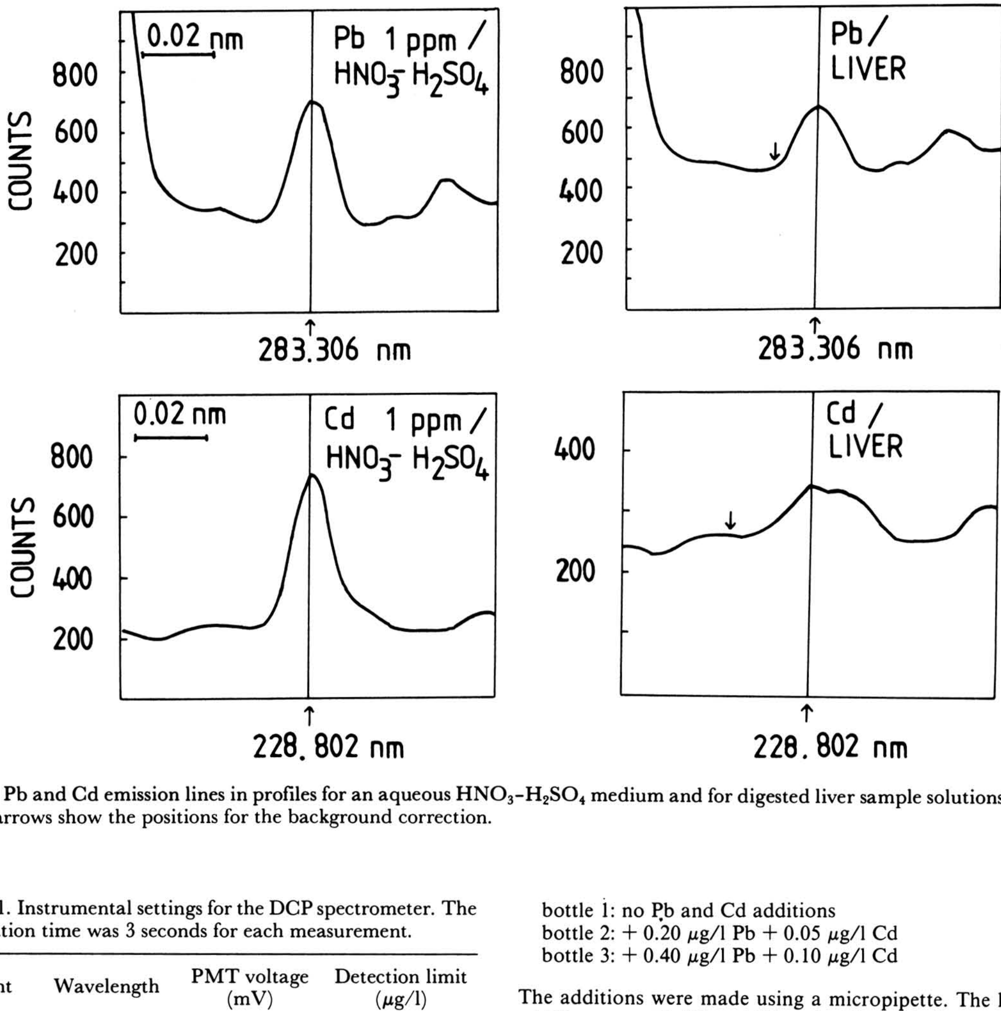

Fig. 1. Pb and Cd emission lines in profiles for an aqueous HNO_3–H_2SO_4 medium and for digested liver sample solutions. The small arrows show the positions for the background correction.

Table 1. Instrumental settings for the DCP spectrometer. The integration time was 3 seconds for each measurement.

Element	Wavelength	PMT voltage (mV)	Detection limit (μg/l)
Pb	283.306	700	0.02
Cd	228.802	850	0.005

to 50 ml with distilled and deionized water and removed to plastic bottles.

A Spectra Span III B single channel plasma emission instrument consisting of a DCP source and an echelle monochromator was used for the Pb and Cd determinations. The instrumental parameters of the spectrometer and the detection limits reported by the manufacturer for the analyte lines used are given in Table 1.

Because of the low Pb and Cd concentrations in the solutions to be analyzed and the strong background emission of the sample solutions, the standard addition method with background correction was used for each determination. Fig. 1 shows the Pb and Cd emission line profiles for an aqueous HNO_3–H_2SO_4 medium and the digested liver solutions. Three portions of 15 ml were taken from each sample solution for this purpose, and the following standard additions were performed:

bottle 1: no Pb and Cd additions
bottle 2: + 0.20 μg/l Pb + 0.05 μg/l Cd
bottle 3: + 0.40 μg/l Pb + 0.10 μg/l Cd

The additions were made using a micropipette. The largest addition was 0.400 ml/15 ml. The relative standard deviations varied between 1.6 and 15.6 %, and 0.9 and 14.8 % respectively for the Pb and Cd determinations.

3. Results and discussion

The highest mean liver tissue concentration of lead (per fresh weight) was found in the hares killed on the Oulu University campus, that recorded for the corresponding sample from Värriötunturi being considerably lower (Fig. 2). The concentration level was naturally lowest of all in the livers of the rabbits reared under laboratory conditions (Fig. 2). In the case of the muscle tissue the situation was a little different, the concentration being markedly high at the campus site in 1981, but otherwise at a relatively low level (Fig. 2).

Table 2. Maximum and minimum concentrations of lead and cadmium (mg/kg fresh weight) in liver and muscle samples from mountain hares captured in Oulu (I–II) and Finnish Forest Lapland (III) (for details, see material and methods), and from laboratory rabbits (IV).

		Pb liver		Pb muscle		Cd liver		Cd muscle	
	N	max.	min.	max.	min.	max.	min.	max.	min.
I	5	1.15	0.55	1.76	0.91	0.26	0.08	0.015	0.01
II	5	1.18	0.74	0.70	<0.20	0.37	0.24	0.18	<0.05
III	2	0.54	0.39	0.51	<0.10	0.52	0.40	0.54	<0.06
IV	3	0.38	0.1	0.57	0.10	0.26	0.18	0.45	0.06

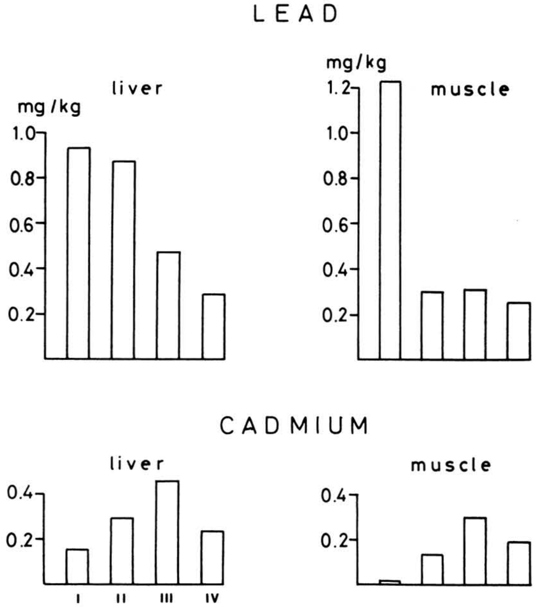

Fig. 2. Mean lead and cadmium concentrations in liver and muscle samples from mountain hares captured in Oulu (I–II) and E Finnish Forest Lapland (III) (for details, see material and methods), and from laboratory rabbits (IV).

Cadmium concentrations showed similar patterns in the liver and muscle tissues (Fig. 2). The highest concentration was found in both cases in the hares caught in the Värriötunturi fell area (Fig. 2, Table 2), with a slight increasing trend to be found in the hares from the university campus site from 1981 to 1982 (Fig. 2).

Concentrations of lead and cadmium are generally known to be high in the tissues of animals living in the immediate vicinity of factories working with these heavy metals (review in Martin & Coughtrey 1982). Wójcik (1980) shows that the highest concentration of lead in the hare is to be found in its liver and that females are more easily contaminated than males. High lead concentrations may cause abnormalities in the organs and physiology of lagomorphs, and Lorenzo et al. (1978) have shown that small rabbits of age 2 to 30 days may develop such abnormalities when ingesting more than 2.8 mg of Pb per day. No abnormalities were found in the present hares (31 exx. altogether).

Considerable inter-individual variation was found in the maximum and minimum concentrations of lead and cadmium (Table 2). It is significant that the minimum value for lead in the muscle tissue at the university campus site in 1981 was higher than the maximum for the same element the following year. It is likely that the lead concentration in the hares browsing during the winter in the area around the university campus will be generally relatively high. In the early winter of 1982 the ground remained snowless for a long time, so that hares in their white winter fur were easily recognizable in the terrain. Thus, they may have been eating annual plants for longer than usual. Sharma & Shupe (1977) found a significant correlation between cadmium concentrations in the livers of animals and the surrounding vegetation.

Tataruch & Onderscheka (1981b) similarly found mercury contamination to be more serious during the winter than in summer, the slow-growing plant tissues which are usually eaten in wintertime obviously having more time to accumulate heavy metals and natural and artificial fall-out (see also Kauranen et al. 1971). This is an apparent explanation for the major occurrence of cadmium in the liver and muscle tissues in the wild area of Värriötunturi (Fig. 2). 46–62 % of the tracks of mountain hares studied during two winters showed them to be feeding on birch (*Betula pubescens* ssp. *tortuosa*), from which they eat the mature growth-form twigs and often discard the juvenile ones (Pulliainen 1972, 1982, unpubl. data). The mountain birches of this area grow very slowly.

Pulliainen (1982, 1983) has shown that mountain hares inhabit only their most favoured habitat(s) during a population low, while in peak winters they also occur in less favoured habitats (the refuge theory). Since the different plant species show different reactions to heavy metal contamination (review in Martin & Coughtrey 1982), the population phase and the habitats of the animals must be taken into account when assessing the data on the concentration of these metals. Thus the hares of northern Finland, for instance, tend to gather on the roadsides in late winter and early spring to feed on the grass and other plants available there, and the accumulation of lead from the exhaust gas of cars in these plants is a well-known phenomenon (see Scanlon 1979, Getz et al. 1979). Tataruch & Onderscheka (1981a) show how wind direction and shelter offered by bushes has an effect on the lead concentration of brown hares (*Lepus europaeus*).

Valtonen & Vikberg (1982), studying cadmium concentrations in the liver and kidneys of the moose (*Alces alces*), found that the latter in particular were contaminated, the concentrations increasing with the age of the animals, and reaching levels well in excess of the maximum permitted in foodstuffs (0.2 mg/kg in the liver). Cadmium concentrations were high throughout the country. This finding is interesting, since mountain hares and the moose eat similar woody plants in winter (e.g. birch, willow and juniper), and the present mountain hares also had too much cadmium in their livers in most cases (Fig. 2, Table 2). On the other hand, the muscles of the moose usually contain less than 0.1 mg/kg cadmium (Valtonen & Vikberg 1982), whereas although the minimum concentrations of cadmium in the muscles of the present mountain hares were below this limit, the maximum value at Värriötunturi was in excess of 0.5 mg/kg (Table 2).

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